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Fuel Purging of Cascaded Fuel Cell Stack

Technical Field

This invention relates to rapid purging of fuel cell stack fuel flow fields and reactant manifolds, such as during startup and
5 shutdown.

Background Art

To achieve very high fuel utilizations, in excess of 95%,
when operating a fuel cell stack on pure hydrogen, a cascade fuel
flow field, illustrated in Fig. 1, comprises a plurality of groups 10-12
10 of fuel cells 13 arranged in flow-series relationship so that fuel from a
source (not shown) passing through a fuel inlet valve 16 enters a fuel
inlet manifold 17, flows through a first group 10 of fuel cells 13,
then enters a first turn-around manifold 19, then flows through the
second group 11 of fuel cells 13, thence through a second turn-
15 around manifold 20 and through the third group 12 of fuel cells 13,
to an exit manifold 22. For a typical 20 kilowatt fuel cell stack, the
first group 10 has a large number of cells 13, which may be on the
order of 95 or 105 cells, the second group 11 has a lesser number of
cells 13, which may be on the order of 30-40 cells, and the third
20 group 12 may have on the order of 5 to 15 cells. As is known, this
assures that all of the cells get adequate hydrogen even with high
hydrogen utilization, provided that the last group of cells 12 get
adequate hydrogen.

In commonly owned, copending U.S. patent application Serial
25 No. 09/742,481, filed December 20, 2000, it is shown that the more
rapidly the fresh hydrogen-containing fuel flows through the anode
flow field upon start-up, to displace the air therein, the quicker the

hydrogen/air interface moves through the anode flow field, and the less time there is for the occurrence of corrosion of the platinum catalyst and catalyst support. In a similar fashion, it is known that the more quickly purge-air is passed through the anode upon shut-down, the less opportunity there is for hydrogen/oxygen interaction, which creates a safety hazard and may cause undesirably large voltage excursions in the cells, as described in commonly owned, copending U.S. patent application Serial No. 09/742,497, filed December 20, 2000.

With the cascade fuel flow field of the type described thus far with respect to Fig. 1, it is impossible to achieve rapid purging of the fuel flow fields since all of the purge gas must pass through a relatively small number of cells in the last cascade (the third group 12). This problem is a large contributor to the degradation of the first cascade (group 10) in fuel cell stacks employing cascade fuel flow fields, which in turn has impeded the adoption of the cascade design.

An alternative purge process may utilize inert gas, such as nitrogen, to purge the cell on shut-down; however, addition of an inert gas to a fuel cell system adds weight, cost and complexity which is unsuited for fuel cell powerplants used to power vehicles. Furthermore, the rapid deployment of hydrogen into the fuel flow fields upon startup, following an inert gas purge on shutdown, still remains a problem in a cascaded fuel flow field design.

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Disclosure of Invention

Objects of the invention include: provision of a rapid purge in a fuel cell stack having cascade fuel flow fields; a fuel cell stack having the high-fuel-utilization advantage of a cascade fuel flow field

without the purge problems heretofore associated therewith; an improved fuel cell stack utilizing cascade flow fields which has no unusual degradation of catalysts and other parts as a consequence of frequent shut-down and start-ups.

5 According to the present invention, a cascade reactant flow field of a fuel cell stack has at least one additional fuel inlet valve to provide inlet fuel directly to each cascade of the stack and at least one additional exhaust valve to remove fuel directly from each cascade of the stack.

10 The invention may be used not only for rapid deployment of fuel into the fuel flow field during start-up, but may also be used for a rapid purge of the fuel flow field with air during shut-down, provided the air is made available to the normal fuel inlet ports in an obvious fashion within the skill of the art.

15 Other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of exemplary embodiments thereof, as illustrated in the accompanying drawing.

Brief Description of the Drawings

20 Fig. 1 is a schematic diagram of the fuel flow system of a fuel cell stack having a three-group cascade fuel flow field, with valves adjusted for normal fuel cell operation.

25 Fig. 2 is a schematic diagram of the fuel flow system of a fuel cell stack having a three-group cascade fuel flow field, with valves adjusted for a rapid purge of the fuel flow fields, in accordance with the invention.

Fig. 3 is a schematic diagram of the fuel flow system of a fuel cell stack having a three-group cascade fuel flow field, with

rotating external manifold gates adjusted for normal fuel cell operation.

Fig. 4 is a schematic diagram of the fuel flow system of a fuel cell stack having a three-group cascade fuel flow field, with 5 rotating external manifold gates adjusted for a rapid purge of the fuel flow fields, in accordance with the invention.

Fig. 5 is a schematic diagram of the fuel flow system of a fuel cell stack having a three-group cascade fuel flow field, with 10 sliding internal manifold gates adjusted for normal fuel cell operation.

Fig. 6 is a schematic diagram of the fuel flow system of a fuel cell stack having a three-group cascade fuel flow field, with 15 sliding internal manifold gates adjusted for a rapid purge of the fuel flow fields, in accordance with the invention.

15 Mode(s) for Carrying Out the Invention

Referring to Fig. 1, during the production of electricity in 20 normal fuel cell operation mode, a microcontroller 25 provides a signal on a line 26 to cause the fuel inlet valve 16 to be open, to provide fuel to the inlet manifold 17, the processor 25 also provides a signal on a line 27 to cause a normal fuel outlet valve 23 to be 25 open. Under this condition, the fuel enters the inlet manifold 17, passes through the group 10 of cells 13, into the first turn-around manifold 19, through the group 11 of cells 13, through the second turn-around manifold 20, through the group 12 of cells 13, through the exit manifold 22, through the outlet valve 23, and to the exhaust 30.

Referring to Fig. 2, when it is desired to purge the fuel cells 13, the microcontroller 25 provides a signal on a line 32 to cause a purge inlet valve 33 to be open, and provides a signal on a line 35 to

cause a purge outlet valve 36 to be open. Under these conditions, the flow is into both the inlet manifold 17 and into the second turn-around manifold 20; and the flow through the group 10 passes through the first turn-around 19 and through the valve 36 to the exhaust 30, whereas the flow from the valve 33 passes through the second turn-around 20 and through both groups 11 and 12; the flow through group 11 passes through the first turn-around 19 and the valve 36 to the exhaust 30, while the flow through the second group 12 passes through the exit manifold 22 and the normal exhaust valve 23 to the exhaust 30. Thus, the flow is directly into each cascade (each group 10-12), and the exhaust is directly from each cascade (each group 10-12). The fuel inlet means, valves 16 and 33, are thus settable in a first condition, valve 16 open and valve 33 closed, or in a second condition, both inlet valves open. Similarly, the fuel outlet means, valves 23 and 36 are settable in a first condition, valve 23 open and valve 36 closed, or in a second condition, both outlet valves open.

The fuel cell stack of the invention may include a recycle loop 38 driven by a pump 39, all in a conventional fashion; however, the use of a recycle loop is optional.

A second embodiment of the invention is illustrated in Fig. 3. Therein, instead of purge fuel valves 33, 36, the embodiment of Fig. 3 employs rotatable manifold gates 40, 41 each of which is connected by suitable gearing 42, 43 to a corresponding motor 44, 45. With the gates 40, 41 as shown, which is the case during normal operation for the production of electricity, flow will be from the inlet manifold 17, through the first group 10, through the first turnaround manifold 19, through the second group 11, through the

second turnaround manifold 20, through the third group 12 and the exit manifold 22 to the valve 23.

When the gates 40, 41 are open as illustrated in Fig. 4, as is the case during a purge, the fuel flows from the inlet manifold 17 through group 10 to the first turnaround manifold 19; from the inlet manifold 17 through the second turnaround manifold 20, through both group 11 and group 12, through a portion of the first turnaround manifold 19 and through the exit manifold 22 to the valve 23.

In the embodiment of the invention illustrated in Fig. 5, instead of having external manifolds 17, 19, 20, 22, the fuel cell stack has internal manifolds 50-53, which comprise ports extending through all of the fuel cells 13a in the stack. In accordance with the invention, sliding gates 56, 57 are driven inwardly or outwardly through suitable linkage 58, 59 by corresponding motors 60, 61. With the sliding gates closed as shown in Fig. 5, which is the case during normal operation for the production of electricity, the fuel flows from an inlet manifold 50, through the first group 10, through a first turnaround manifold 51, through the second group 11, through a second turnaround manifold 52, through the third group 12, and through an exit manifold 53 to the valve 23.

In Fig. 6, when the sliding gates 56, 57 are open, as is the case during a purge, fuel flows along the inlet manifold 50 and first turnaround manifold 52 into all three groups 10, 11, 12 and then through the first turnaround manifold 51 and the exit manifold 53 to the valve 23.

The embodiments of Figs. 4-6 may have a certain degree of fuel leakage, but such fuel leakage may be tolerable between the inlet manifold and the second turnaround manifold. Fuel leakage between

the first turnaround manifold and the exit manifold may also be tolerable provided there is a recycle loop 38, to avoid wasting fuel.

Although shown for a cascade fuel flow field having three groups 10-12, the invention can obviously be used with a cascade fuel flow field having more groups of cells, simply by providing sufficient means so that, during a purge, each group receives fuel directly, rather than after flowing through another group, and the fuel from each group exhausts directly, rather than flowing through another group.

10 The aforementioned patent applications are incorporated herein by reference.

15 Thus, although the invention has been shown and described with respect to exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made therein and thereto, without departing from the spirit and scope of the invention.

We claim:

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